Gas hydrates and slope stability

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Global warming affects the seabed in many different ways. One way which causes concern is the effect that bottom water warming has on marine gas hydrates. These ice-like crystals of water and gas dissolve, which changes the stability of continental margins. In a worst-case scenario this may facilitate submarine landslides and associated tsunamis that could reach central Europe.

It has long been claimed that there is a connection between gas hydrates and slope stability. The main reason for this is the spatial distribution of bottom simulating reflectors (BSR), which are a proxy for marine gas hydrates and the head walls of slope failures which frequently occur at the same depth.

As gas hydrates are only stable at high pressures and low temperatures, increases in bottom water temperature or drops in sea level may destabilize hydrates. This may then lead to a weakening of slope sediments either directly because the sediments lose the hydrate cement, which holds them together or by the generation of overpressures when hydrates dissociate and rapidly release free gas.

A typical gas hydrate sample showing the laminated structure of sediments (dark) and hydrate layers (white). Photo: IFM-GEOMAR.

Although modelling studies showed that this is a viable scenario, direct geological evidence for this mechanism remained sparse, and the hypothesis was only supported by circumstantial evidence such as negative carbon isotope excursions during times of rapid warming indicating that gas hydrates dissociated.

In 2008, we have made a couple of observations that elucidate the relationship between hydrates and slope failures. When studying in detail the bathymetry of the Storegga Slide which is one of the world's largest and best studied submarine slope failures, we discovered that there is a pronounced difference between the morphology of areas underlain by hydrates and areas without (Micallef et al., 2008).

In this study we used novel geomorphometric techniques to constrain the submarine mass movements that have shaped the north-eastern Storegga Slide and understand the link between different forms of failure. The northeastern part of the Storegga Slide developed in four major events. The first event was triggered in water depths of 1500 – 2000 m. In this event, the surface sediments were removed by debris flows and turbidity currents, and deposited in the Norwegian Sea Basin. Loading of the seabed by sediments mobilised by the first event resulted in the development of an evacuation structure. Loss of support associated with this evacuation structure, reactivation of old headwalls, and seismic loading have activated spreading in the failure surface of event 1 that extended up to the main headwall. In some areas, spreading blocks have undergone high displacement and remoulding. Parts of the spreading morphology and the underlying sediment have been deformed or removed by numerous debris flows and turbidity currents. We conclude that the higher displacement and remoulding of the spread-

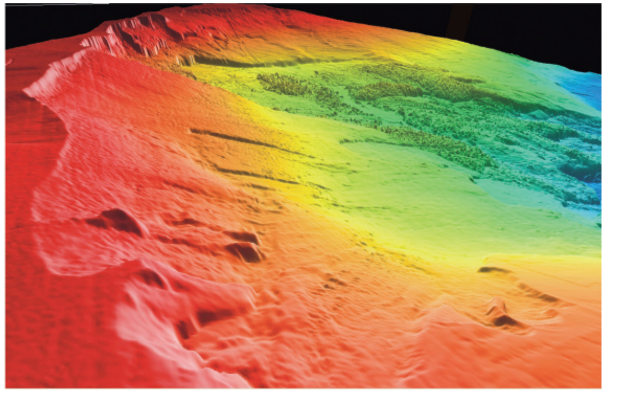

Figure 1: Spatial relationship between morphological units and the distribution of gas hydrate related bottom simulating reflectors show that hydrates control the dynamics of submarine landslides (Micallef et al., 2008). Data courtesy of Ormen Lange license partners.

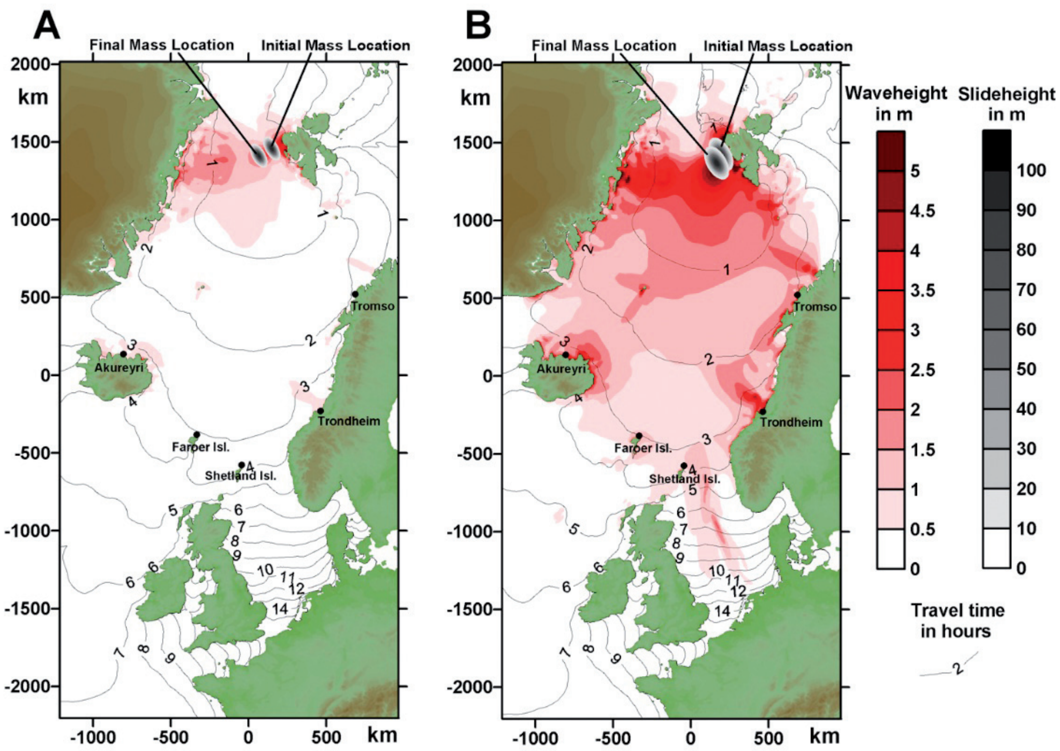

Figure 2: Tsunami heights and travel times for a westward running landslide (A) and a southwestward running slide (B). From Berndt et al., in press.

ing blocks (Figure 1), and their removal by debris flows and turbidity currents, was influenced by increased pore pressures possibly due to gas hydrate dissociation and by lateral variability in the deposition of contourite drifts in palaoeslide scars. The fourth event entailed the compression of sediment from a large debris flow against the spreading areas and the formation of localised shear zones.

These results do not show that the Storegga Slide was triggered by gas hydrate dissociation, but they do show that gas hydrates have a destabilizing effect on submarine slopes, and that their presence can control how submarine landslides develop once they have started. Therefore it is important to understand how gas hydrates respond to climate change in order to assess if submarine slopes will be less stable as global warming continues.

Last summer we surveyed the western margin of Svalbard where the base of the gas hydrate stability zone intercepts the seabed. At exactly this water depth we found significant release of methane gas from the seabed (Westbrook et al., 2008). The data support that this gas release is due to a decadal scale warming of gas hydrates in the surface sediments. This shows that bottom water warming may induce gas hydrate dissociation, which may destabilize the slope.

From studying the Storegga Slide we know that the landslide has caused an up to 22 m high tsunami on the coasts of NW Europe. Therefore we wanted to find out what will happen if the gas hydrate dissociation of Svalbard should induce a submarine landslide as well. So, we have modeled potential tsunamis in collaboration with the GFZ in Potsdam (Berndt et al., in press). The modeling results indicate that a landslide off Svalbard would be associated with a tsunami that would reach central Europe (Figure 2). The tsunami height would crucially depend on the run-out direction of the landslide. As a consequence we have already proposed to monitor the site of gas hydrate dissociation to understand the scale of this process, and we will propose to install a tiltmeter-based tsunami warning system.

References

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